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NONPOINT SOURCE POLLUTION ASSESSMENT OF THE LOWER SUSQUEHANNA RIVER BASIN

DEC 24, 1970

SUSQUEHANNA RIVER BASIN COMMISSION

RESOURCE QUALITY MANAGEMENT & PROTECTION DIVISION

NOVEMBER 1977

The Susquehanna River Basin Commission was created as an independent agency by a Federal-Interstate Compact* among the States of Maryland, New York, Commonwealth of Pennsylvania and the Federal Government. In creating the Commission, the Congress and State Legislatures formally recognized the water resources of the Susquehanna River basin as a regional asset vested with local, State and National interests for which all the parties share responsibility. As the single Federal-Interstate water resources agency with basinwide authority, the Commission's goal is to effect coordinated planning, conservation, management, utilization, development and control of basin water resources among the government and private sectors.

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* Statutory Citations: Federal - Pub.L. 91-575, 84 Stat. 1509 (December, 1970); Maryland - Natural Resources §8-301 (Michie 1974); New York - ECL §21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).

NONPOINT SOURCE POLLUTION ASSESSMENT
OF THE
LOWER SUSQUEHANNA RIVER BASIN

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SUSQUEHANNA RIVER BASIN COMMISSION

1721 NORTH FRONT STREET

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TABLE OF CONTENTS

Page

ABSTRACT.. 1

INTRODUCTION.. 2

Purpose... 2

Scope... 2

Water Quality Program....................................... 3

ACKNOWLEDGMENTS... 4

PHYSICAL SETTING.. 5

Topography.. 5

Climate... 5

Soils... 7

Land Use.. 8

NONPOINT SOURCE POLLUTION ASSESSMENT IN THE LOWER SUSQUEHANNA RIVER BASIN.. 10

Appraisal by Subbasins...................................... 10

Shamokin Creek.. 10
Penn Creek.. 18
Mahanoy Creek... 18
Mahantango Creek.. 19
Wisconisco Creek.. 20
Juniata River... 20
Conodoguinet Creek.. 24
Yellow Breeches Creek....................................... 26
Swatara Creek... 26
W. Conewago Creek... 27
Codorus Creek... 28
Conestoga River... 29
Pequea Creek.. 30
Deer Creek.. 30

Page

COMPARISON OF SUBBASINS.......... 34

Comparison of SRBC & EPA Results.......... 41

Comparison of SRBC Study Results & USGS Sediment Study Results.......... 44

CONCLUSIONS.......... 46

RECOMMENDATIONS.......... 50

BIBLIOGRAPHY.......... 51

Tables

1 -- Percentages of Land Use in the Lower Susquehanna River and Tributary Drainage Areas.......... 9

2 -- Mean Concentrations of Oxidized Inorganic Nitrogen, Ammonia & Total Phosphorus for Monitoring Stations in the Lower Susquehanna Basin.......... 11

3 -- Flow - Concentration Relationships for NO_2-NO_3, NH_3, and TP.......... 34

4 -- Mean Concentration and Mean Flow Relationships.......... 36

5 -- Average Oxidized Inorganic Nitrogen, Ammonia & Total Phosphorus Loadings for Monitoring Stations in the Lower Susquehanna River Basin.......... 37

6 -- Average Loading in Pounds-Per-Day-Per-Square Mile.......... 40

7 -- Comparison of SRBC and EPA Study Results.......... 42

8 -- Comparison of SRBC Results and USGS Sediment Study Results.......... 45

Figures

1 -- Map of Susquehanna River Basin Showing Study Area.......... 6

2 -- Locations of Stream Sampling Stations.......... 16

ABSTRACT

Existing nutrient data from water quality programs of other agencies were utilized to provide an assessment of nonpoint source pollution problems in the tributary streams in the Lower Susquehanna River Basin. Field data collection was not attempted. The existing nutrient data was collected for general water quality information purposes and provided data for accomplishing only a gross assessment of possible pollution from nonpoint sources.

Results of analyses of the data from 14 streams indicated that nonpoint source concentrations of oxidized inorganic nitrogen were evident in segments of 12 streams. Nonpoint source concentrations of ammonia were found in 10 of the 14 streams and indications of nonpoint source influence of phosphorus were found in nine streams. Results of the study indicated that the primary sources of oxidized inorganic nitrogen, ammonia and phosphorus in the Conodoguinet Creek and Yellow Breeches Creek were point source discharges.

Analyses of nutrient loadings in pounds-per-day-per-square mile indicated that the West Conewago Creek in York County, Pennsylvania, and the Conestoga River in Lancaster County, Pennsylvania, were probably the greatest contributors of oxidized inorganic nitrogen. The West Conewago Creek has the greatest loadings in pounds-per-day-per-square mile of ammonia and phosphorus.

INTRODUCTION

Purpose

Nonpoint source pollution affects nearly all streams in the Susquehanna River Basin to some extent. The purpose of the project is to assess the problem and identify problem areas which may warrant detailed studies with the ultimate goal of providing a basis for recommending control measures based upon the impact that identified nonpoint source pollution has upon stream quality.

Scope

The study area includes the tributary streams of the Lower Susquehanna River Basin for which sufficient data were available. The Lower Susquehanna River Basin consists of the basin area downstream of Sunbury, Pennsylvania, to the mouth of the river. Tributary streams for which appropriate nutrient data were available were as follows:

Shamokin Creek
Penn Creek
Mahanoy Creek
Mahantango Creek
Wiconisco Creek
Juniata River
Conodoguinet Creek
Yellow Breeches Creek
Swatara Creek
West Conewago Creek
Codorus Creek
Conestoga River
Pequea Creek
Deer Creek

Certain limitations on the study should be recognized. The assessment is based upon available data from other collection agencies; field data collection was not attempted. In using the available data, limitations included: (1) sampling sites were not ideally located, (2) analyses of grab samples did not reflect conditions throughout the river section - both laterally and vertically, (3) the length of sampling period and sampling frequency (monthly) occasionally were not sufficient to enable a detailed analysis (or in some cases to permit a gross analysis) of the nonpoint source pollution, and (4) point source discharge data primarily for nutrients were incomplete.

Water Quality Program

The Susquehanna River Basin Compact confers broad powers upon the Commission for the management of the water and related resources of the Susquehanna River Basin which include water quality management and control. The Commission's exercise of its authority is articulated in its Comprehensive Plan for the immediate and long-range development and use of the water and related resources of the Basin. The Comprehensive Plan defines the immediate role of the Commission's efforts regarding water quality as the following: coordination of the efforts of Federal, State and local pollution control and management agencies; evaluation of the effectiveness of adopted water quality standards, and direction of attention to special problems. Special water quality problems from point and nonpoint sources include acid mine drainage, effects of heated effluents and nutrient pollution.

ACKNOWLEDGMENTS

Appreciation is expressed to the Department of Environmental Resources, State of Pennsylvania, Department of Natural Resources, State of Maryland, and U.S. Soil Conservation Service and Geological Survey for their invaluable cooperation and assistance in providing information for this study.

PHYSICAL SETTING

Topography

The area discussed in this report (Figure 1) encompasses the drainage area of the Main Stem Susquehanna River from Sunbury, Pennsylvania, downstream to the river mouth. This area lies within the Ridge and Valley, Blue Ridge and Piedmont physiographic provinces. The Valley and Ridge province begins north of the study area and includes the basin area from Sunbury downstream to about ten miles south of Harrisburg, Pennsylvania. It is characterized by steep mountains and ridges separated by broad valleys. Only a small part of the mountainous Blue Ridge province lies in the Susquehanna River Basin between the Yellow Breeches and the Conewago Creeks. Slopes on the Blue Mountain average about 30 percent and are nearly flat in the valleys. The Piedmont province begins about ten miles south of Harrisburg, Pennsylvania and contains terrain that is gently rolling to hilly.

Climate

The Lower Susquehanna River Basin has a continental type of climate, modified by moisture periodically entering the area from the Gulf of Mexico and the Atlantic Ocean. As a result, precipitation is generally greater and temperatures less extreme than would otherwise be the case (Susquehanna River Basin Study Coordinating Committee, 1970).

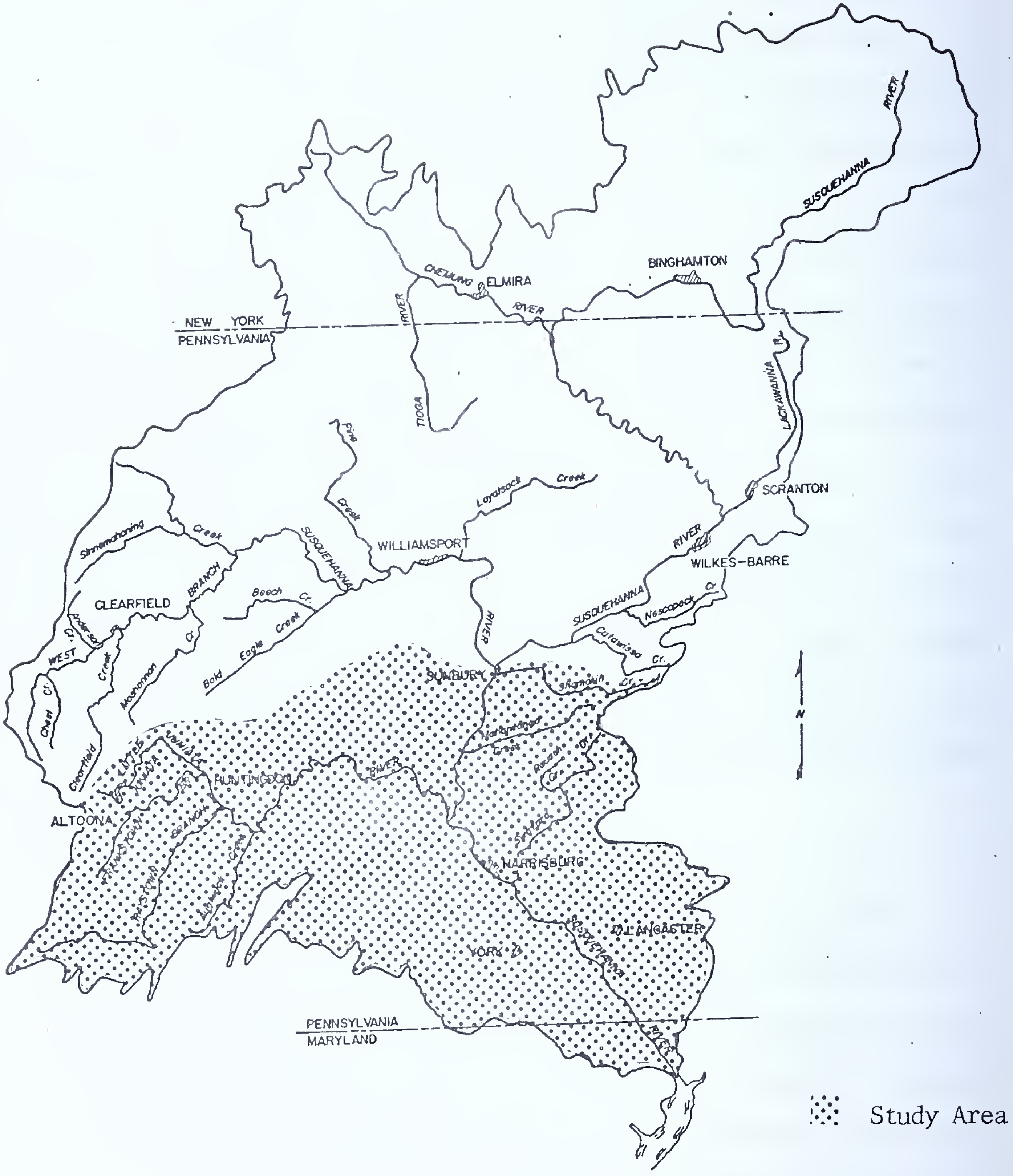

Figure 1 -- Map of Susquehanna River Basin showing study area.

The atmospheric conditions within the Basin are primarily controlled by high and low pressure systems that normally move eastward across the United States with average wind speed of about 10 mph.

Storms developing along the southeastern coast of the United States periodically bring moderate to heavy precipitation to the Basin because of the general upslope motion of the air as it is forced to rise over the higher terrain.

Yearly rainfall over the lower Susquehanna generally averages between 39 inches and 40 inches with the most rain falling in the spring and the least in the fall. About 45 percent is runoff and the remainder infiltrates to the groundwater reservoir or is returned to the atmosphere through evapotranspiration.

Soils

The Valley and Ridge province is an area of northeast-southwest oriented parallel, steep-sided, wooded sandstone ridges separated by hilly shale and limestone valleys. The eastern most portion of this section consists of wide shale and limestone areas of low hills and moderate relief. The soils are formed in material weathered from underlying rocks or from colluvial material on the lower ridges.

Soils of the weathered sandstone ridges are mostly moderately deep to deep, and well drained. The very stony soils of the lower ridges are deep, moderately well to poorly drained and the very stony soils of the shale valleys are mostly moderately deep to shallow, well to moderately well drained, with moderate to steep slopes. Soils of the limestone valleys are predominately deep, well drained, productive and in cropland.

The Piedmont province is an area of low relief and broad gentle slopes underlain by red Triassic shale in the northern part and by schist, gneiss, and quartzite in the southern portion.

The ridge soils are mostly deep, well drained and very stony with the soils formed over the shales and other softer rocks being moderately deep to deep, well to poorly drained, and generally very fertile.

Land Use

The Lower Susquehanna River Basin below Sunbury, Pennsylvania, is comprised of approximately 43.6 percent agricultural lands, 46.4 percent forest lands, 1.0 percent open waters, 1.5 percent urban lands and 3.3 percent disturbed lands (quarries, strip mines). The remaining 4.3 percent of the land consists of highways, railways, public lands, etc. The agricultural and urban lands are generally located in the flatter river valleys with the forest land located on the higher and steeper slopes.

Table 1 shows the land use percentages for each of the tributary drainage areas.

TABLE 1

PERCENTAGES OF LAND USE IN THE LOWER SUSQUEHANNA RIVER AND TRIBUTARY DRAINAGE AREAS

Drainage Area	Agriculture %	Disturbed %	Water %	Urban %	Forest %	Other %
Penn Creek	26.40	3.40	0.40	0.60	69.10	0.06
Shamokin Creek	38.40	10.90	2.50	1.10	43.30	1.57
Mahanoy Creek	42.70	12.43	1.61	0.78	41.05	1.42
Mahantango Creek	44.79	8.02	0.09	0.05	45.53	1.22
Wiconisco Creek	40.86	7.54	0.11	0.57	49.86	1.01
Conodoguinet Creek	44.60	0.70	1.90	4.90	37.60	10.60
Yellow Breeches Creek	38.90	0.40	0.10	0.50	53.20	6.80
Swatara Creek	52.00	7.00	0.12	1.20	37.10	2.50
Conewago Creek (W)	54.00	0.90	0.50	2.20	33.70	8.70
Codorus Creek	53.40	1.70	1.30	4.50	26.60	12.40
Muddy Creek	50.50	0.50	0.10	0.30	35.80	12.70
Conestoga Creek	59.10	0.90	1.30	1.10	31.20	6.30
Pequea Creek	60.30	1.60	0.50	1.00	25.80	10.70
Octoraro Creek	60.70	2.50	0.90	0.40	25.60	9.90
Juniata River	32.30	2.75	0.75	0.90	63.24	0.06
Deer Creek	65.00	----	----	----	29.00	6.00
L. Susquehanna River Basin	43.57	3.31	0.98	1.45	46.37	4.32

For the purpose of data evaluation, the year was divided into low, moderate and high flow periods based on seasonal variations of flows. The low flow period includes the months of June through October; moderate flow, the months of November through February; and the high flow period includes the months of March through May.

Mean concentrations of oxidized inorganic nitrogen (NO_2 + NO_3), ammonia, and phosphorus, and average flows during each flow period for tributary streams to the main stem Susquehanna River are shown in Table 2. Locations of monitoring stations are shown on Figure 2.

Appraisal by Subbasins

Shamokin Creek - The drainage area is located in the Valley and Ridge Province generally characterized by steep mountains and ridges separated by broad valleys. Major land use in the Shamokin Creek drainage area consists of approximately 38 percent agricultural land, 43 percent forest, 11 percent disturbed lands and one percent urban lands. The upper reaches of the drainage area above Shamokin, Pa. consist of primarily strip mines, forested land and urban land, the largest of which are Shamokin and Mount Carmel. The topography is generally mountainous. The lower reaches of the drainage area below Shamokin consist of predominantly agricultural land and forested land with the major urban center being Sunbury at the confluence with the Susquehanna River. Mean concentrations of

MEAN CONCENTRATIONS OF OXIDIZED INORGANIC NITROGEN, AMMONIA AND TOTAL PHOSPHORUS FOR MONITORING STATIONS IN THE LOWER SUSQUEHANNA BASIN, IN MILLIGRAMS PER LITRE

Station	Flow (cfs)			$NO_2 + NO_3$ (mg/1)			NH_3 (mg/1)			TP as P (mg/1)		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Penn's Crk. nr. Mouth	---	---	---	0.872	1.376	1.250	0.061	0.050	0.225	0.070	0.062	0.055
Shamokin Crk. in Shamokin Twp.	54	98	93	0.251	0.620	0.929	2.601	1.258	1.019	1.193	0.195	0.555
Mahanoy Crk. nr. Mouth	---	---	---	1.316	1.938	1.102	0.225	0.400	0.500	0.175	0.130	0.165
Mahantango Crk. nr. Dalmatia	60	251	261	2.385	2.815	3.364	0.077	0.359	0.102	0.077	0.070	0.070
Wisconisco Crk. at Millersburg	---	---	---	1.510	1.637	1.598	0.070	1.222	0.200	0.101	0.090	0.082
Juniata River												
Beaver Dam Br., Juniata R. nr. Confl. w/ Frankstown Br.	---	---	---	2.807	1.722	1.712	0.465	0.197	0.110	1.038	0.467	0.290
Frankstown Br. Juniata R. at Penn Central R.R. Bridge, Woodbury Twp., Blair Co.	128	459	948	2.239	2.830	1.867	0.101	0.115	0.225	0.386	0.270	0.175
Little Juniata R. at Rt. 220 Bridge in Antis Twp.	---	---	---	4.601	1.520	0.749	0.112	0.117	0.120	1.118	0.819	0.160

--- Data not available.

Page 1 of 5

Station	Flow (cfs)			NO2 + NO3 (mg/1)			NH3 (mg/1)			TP as P (mg/1)		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Little Juniata R. at Spruce Crk.	181	224	600	1.579	1.444	1.114	0.103	0.183	0.107	0.396	0.443	0.213
S. Bald Eagle Crk. at Tyrone	86	66	117	0.501	0.486	0.481	0.058	0.062	0.170	0.147	0.077	0.345
Juniata R. at Huntingdon	378	869	1,931	2.040	1.963	1.372	0.172	0.053	0.133	0.340	0.190	0.116
Bobbs Crk. at Reynoldsdale	---	---	---	0.999	1.413	1.385	0.092	0.075	0.163	0.062	0.065	0.060
Dunning Crk. nr. Mouth	45	112	612	1.775	1.057	1.361	0.086	0.070	0.150	0.184	0.060	0.080
Raystown Br. Crk. Rt. 913 Bridge nr. Saxton	458	409	747	1.122	1.678	1.166	0.115	0.050	0.137	0.155	0.070	0.083
Juniata R. at Mapleton	765	1,933	3,258	1.375	1.080	1.214	0.126	0.599	0.153	0.240	0.170	0.103
Aughwick Crk. at Aughwick Mills	---	---	---	0.533	0.671	0.656	0.122	0.083	0.112	0.606	0.080	0.047
Kishacoquillas Crk. at Reedsville	---	---	---	2.920	1.692	3.112	0.116	0.040	0.040	0.124	0.090	0.070
Honey Crk. at Reedsville	---	---	---	0.877	1.021	1.039	0.105	0.023	0.078	0.120	0.063	0.075
Kishacoquillas Crk. at L.R. 44002 Bridge	---	---	---	2.726	3.292	2.638	0.114	0.013	0.125	0.116	0.113	0.070
Kishacoquillas Crk. at Lewistown	---	---	---	2.618	2.192	2.438	0.115	0.080	0.140	0.180	0.140	0.073
Jacks Crk. at Lewistown	---	---	---	2.532	3.410	2.904	0.112	0.020	0.100	0.123	0.117	0.075

Station	Flow (cfs)			NO_2 + NO3 (mg/1)			NH3 (mg/1)			TP as P (mg/1)		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Tuscarora Crk. at Port Royal	---	---	---	2.131	1.053	0.769	0.064	0.053	0.077	0.210	0.063	0.037
Juniata R. at Newport	1,306	3,196	7,722	0.694	0.654	1.176	0.092	0.070	0.140	0.142	0.060	0.122
Conodoguinet Crk. at T. 574 Bridge in Middlesex Twp.	354	393	977	3.291	---	2.470	0.140	---	0.092	0.295	---	0.327
Conodoguinet Crk. at L.R. 21016 Bridge in Hampden Twp.	---	---	---	3.121	2.414	2.541	0.092	0.030	0.127	0.202	0.120	0.155
Yellow Breeches Crk. at Old U.S. 111 Bridge, Fairview Twp.	189	208	441	2.344	1.698	1.733	0.098	0.050	0.100	0.158	---	0.120
Swatara Crk. at Middletown	---	---	---	5.450	4.637	2.766	0.094	0.157	0.352	0.297	0.157	0.143
W. Conewago Crk. nr. Manchester	140	357	2,965	1.339	0.818	2.067	0.137	0.030	0.207	0.182	0.110	0.200
S. Br. Codorus Crk. nr. York	42	47	140	3.681	3.028	4.167	0.180	0.030	0.197	0.100	0.070	0.117
Conestoga Crk. at Lancaster	264	366	440	6.432	9.049	8.329	0.062	0.142	0.227	0.268	0.252	0.510
Conestoga Crk. at Rock Hill	---	---	---	7.184	8.876	8.638	0.253	0.390	0.330	0.601	0.482	0.784
Pequea Crk. at PTR 324, Martic Twp.	---	---	---	6.446	7.628	7.804	0.077	0.058	0.170	0.178	0.369	0.422

Station	Flow (cfs)			$NO_2 + NO_3$ (mg/1)			NH_3 (mg/1)			TP as P (mg/1)		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Little Deer Crk. off Harris Mill Rd. 0.7 Mile Above Mouth LDE 0007	0.72	2.90	2.31	3.44	3.21	2.74	0.02	0.01	0.04	0.16	0.11	0.02
Deer Crk. at Harris Mill Rd. Crossing DER 0437	12.20	34.80	38.80	3.87	3.50	2.99	0.03	0.01	0.04	0.05	0.19	0.03
Ebaughs Crk. at Harris Mill Rd. Crossing EBA 0001	8.42	23.40	15.15	3.80	4.70	3.56	0.03	0.01	0.04	0.03	0.05	0.02
Deer Crk. at Bond Rd. Crossing DER 0424	2.85	68.10	68.70	3.73	2.53	2.79	0.02	0.01	0.04	0.01	0.11	0.01
Unnamed Trib. at Lieb Rd. Crossing UDR 0005	1.18	2.62	2.64	3.85	1.70	2.80	0.03	0.01	0.04	0.03	0.02	0.17
Deer Crk. at Green Rd. Crossing DER 0399	29.27	91.70	83.27	3.61	2.10	2.96	0.02	0.01	0.04	0.15	0.11	0.02
Deer Crk. at Carea Rd. Bridge DER 0328	---	---	---	2.05	---	2.82	0.03	---	0.02	0.04	---	0.02
Big Br., Deer Crk. at Eden Mill Rd. BIG 0002	---	---	---	1.77	---	2.10	0.04	---	0.02	0.06	---	0.02
Falling Br., Deer Crk. at Red Bridge Rd. FLL 0001	---	---	---	2.14	---	2.51	0.08	---	0.02	0.04	---	0.02

Station	Flow (cfs)			$NO_2 + NO_3$ (mg/l)			NH_3 (mg/l)			TP as P (mg/l)		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Deer Crk. at Bridge on Md. 165 DER 0282	---	---	---	2.02	---	2.75	0.04	---	0.02	0.08	---	0.02
Little Deer Crk., Deer Crk. at Bridge on Md. 165 LDC 0006	---	---	---	1.50	---	2.20	0.03	---	0.02	0.09	---	0.02
Deer Crk. at St. Clair Bridge Rd. DER 0263	---	---	---	1.89	---	2.63	0.03	---	0.02	0.04	---	0.02
Deer Crk. at Cherry Hill Rd. Bridge USGS 01580000 DER 0231	---	---	---	1.70	---	2.46	0.03	---	0.03	0.03	---	0.02
Deer Crk. at Walters Mill Rd. Above Stout Bottle Br. DER 0175	---	---	---	1.75	---	2.20	0.04	---	0.02	0.05	---	0.02
Deer Crk. at U.S. Rt. 1 USGS 0580200 DER 0124	---	---	---	1.65	---	2.40	0.06	---	0.03	0.42	---	0.02
Deer Crk. at Md 136 Bridge DER 0090	---	---	---	1.73	---	2.04	0.06	---	0.02	0.06	---	0.02
Deer Crk. at Noble Mill Rd. Bridge DER 0069	---	---	---	1.73	---	2.57	0.14	---	0.02	0.05	---	0.02
Deer Crk. at Stafford Bridge Rd. DER 0015	---	---	---	1.63	---	2.20	0.06	---	0.02	0.14	---	0.02
Deer Crk., Mouth at Railroad Bridge DER 0001	---	---	---	1.60	---	2.20	0.06	---	0.02	0.11	---	0.02

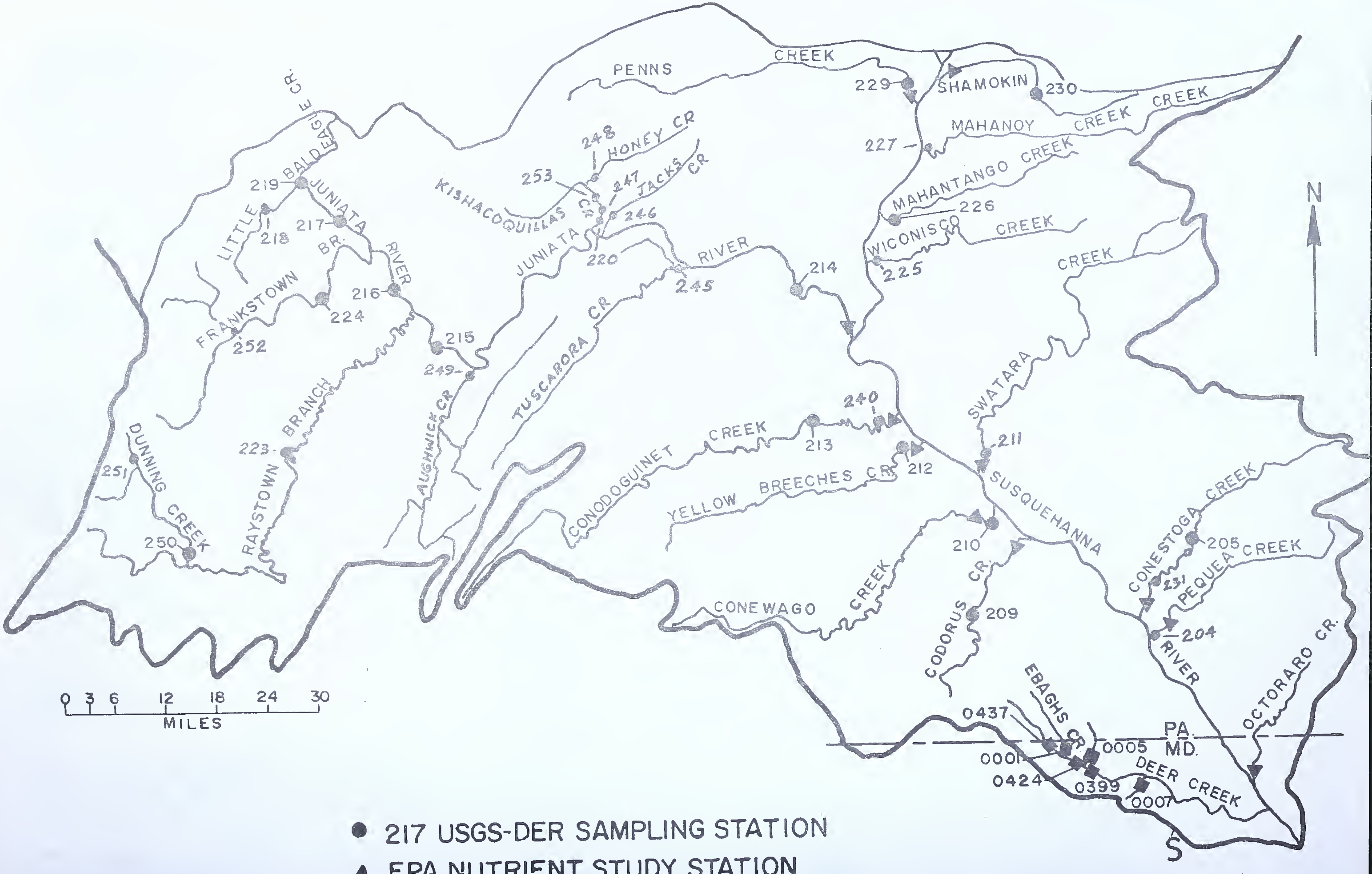

FIGURE 2 LOCATIONS OF STREAM SAMPLING STATION

oxidized inorganic nitrogen (NO_2 + NO_3) show an increase in concentration during the higher flow periods at the monitoring station located just below Shamokin, Pennsylvania, indicating that nonpoint sources exert a major influence on this reach. Ammonia concentrations indicate that point sources are the primary contributors of ammonia. Regression of the data to determine flow-concentration relationships corroborate the indications that nonpoint sources exert a major influence on oxidized inorganic nitrogen content in the upper reaches of Shamokin Creek upstream of Shamokin. The regression data also indicate that ammonia in this reach of the stream is due primarily to point source discharges. Phosphorus data gave conflicting results. Phosphorus concentrations indicate that point sources are the primary contributors of phosphorus, but regression data indicate that nonpoint sources are the primary contributors. Due to the limited quantity of the data, the concentrations are probably not representative of average conditions in the upper reaches of Shamokin Creek.

The Environmental Protection Agency's Annapolis Field Office conducted a nutrient transport study in the lower Susquehanna River basin during the period June 1971 - May 1972. A sampling station was established near the mouth of Shamokin Creek below Sunbury, Pennsylvania. The results of the EPA study indicated that nonpoint sources had a major influence on oxidized inorganic nitrogen content in Shamokin Creek and that point sources were the primary contributors of TKN and phosphorus in the lower reaches of the creek.

It appears that nonpoint sources of oxidized inorganic nitrogen exert a major influence throughout the Shamokin Creek. Primary sources of TKN and ammonia appear to be point source discharges. Phosphorus data indicate that nonpoint sources may exert a major influence in the upper reaches above Shamokin and that point sources are probably the primary sources in the lower reaches.

Penn Creek - The Penn Creek drainage area lies in the Valley and Ridge Province and consists of approximately 26 percent agricultural land, 69 percent forest, one percent urban land and three percent disturbed lands. The major part of the agricultural land is located in the lower reach of the Penn Creek downstream from Penn Creek, Pennsylvania and in the stream valleys of Middle Creek. The upper reaches of the drainage area are predominantly forested land. The monitoring station is located near the mouth of Penn Creek upstream from Selinsgrove, Pennsylvania. Nutrient data collected at this station indicate that oxidized inorganic nitrogen and ammonia concentrations increased with flows implying that nonpoint sources exert a major influence. Phosphorus concentrations imply that nonpoint sources are not major contributors of phosphorus into Penn Creek. Corresponding flow data were not available to establish flow-concentration relationships. Results of the EPA nutrient transport study at the same station indicated that oxidized inorganic nitrogen in Penn Creek was influenced primarily by nonpoint sources, while TKN and phosphorus were primarily from point sources.

Mahanoy Creek - Mahanoy Creek drainage area lies in the Valley and Ridge Province and consists of approximately 43 percent agricultural land, 41 percent forest, 12 percent disturbed lands and one percent urban land. The upper reaches of the drainage area above Ashland are primarily in strip mines. Downstream from Ashland the Mahanoy Creek flows through an area that is primarily forested to Dornsife, Pennsylvania, then agricultural land to its confluence with the Susquehanna River. Nutrient data collected near the mouth of the stream indicated some increase in concentrations of nitrogen and ammonia with flow implying nonpoint source influence. Phosphorus concentrations showed slight decrease during the higher flow period implying point source influences. However, these indications may not reflect the actual conditions, and corresponding flow data were not available for statistical determination of flow-concentration relationships. Furthermore, the data may be indicative of possible influences of the agricultural land on the lower reach of the Mahanoy Creek. Additional data are necessary before any conclusions concerning the entire drainage area can be made.

Mahantango Creek - Land use in the Mahantango Creek drainage area comprises about 46 percent agricultural land, 45 percent forest and 8 percent disturbed lands. The Mahantango Creek and its tributaries flow through primarily agricultural lands in the valley with the forested areas being located on the higher and steeper ridges. Nutrient data collected near the mouth of the Creek indicate predominantly nonpoint source influence on oxidized inorganic nitrogen, ammonia and phosphorus concentrations. This probably reflects the effect of largely agricultural land immediately adjacent to the stream. Regression analyses showed a positive relationship between flow and concentration to support the indications that nonpoint sources were the primary sources of nutrients.

Wisconisco Creek - The Wisconisco Creek drainage area is comprised of about 41 percent agricultural lands, 50 percent forest and seven percent disturbed lands. The upper reaches of the drainage area are predominantly forests and the lower reach is primarily in agricultural land. The mean concentrations of nutrient data collected at Millersburg near the mouth of the Creek indicate an increase in concentration of oxidized inorganic nitrogen and ammonia during the higher flow periods. Phosphorus data indicated a decrease in concentration during the higher flow periods. Flow data corresponding to the chemical data were not available for determination of flow-concentration relationships to support these indications. Additional data need to be collected to determine whether the entire drainage area is subject to nonpoint source influence for oxidized inorganic nitrogen and ammonia or whether it reflects primarily the effects of the predominantly agricultural lands in the lower drainage area.

Juniata River - The drainage area is in the Valley and Ridge Province generally characterized by steep mountains and ridges separated by broad valleys. The Juniata River drainage area is comprised of approximately 63 percent forested land, 32 percent agricultural lands, 2.75 percent disturbed lands and one percent urban land. The major part of the upper reaches of the Juniata River above Mapleton is in forest with agricultural lands occurring in relatively narrow strips along the stream valleys. In the lower reach of the Juniata River below Mapleton, agricultural lands are predominant and occur in broad areas along the tributary streams. Mean oxidized inorganic nitrogen concentrations for seven of nine monitoring stations in the upper reaches of the Juniata River above Mapleton are generally lower during the higher flow periods than during the low flow period indicating that nonpoint source discharges are not major sources of oxidized inorganic nitrogen in this reach of the Juniata River. Exceptions were noted at stations on Bobbs Creek at Renoldsdale (a tributary to Dunning Creek which feeds into the upper most reaches of Raystown Branch, Juniata River), and on the Raystown Branch near Saxton. The concentrations at these stations increased with increase in flows, with the highest concentration occurring during the moderate flow period when temperatures and biological activity are lowest. Regression analyses of data for six of the seven monitoring stations in the upper reaches with appropriate flow data supported the indications derived from the mean concentrations. An exception was noted at the Dunning Creek stations, where the mean concentrations indicated a decrease in oxidized inorganic nitrogen during the higher flow periods, but the regression analyses showed an increase with flows.

In the reach of the Juniata River from Mapleton downstream to Newport, the mean oxidized inorganic nitrogen concentrations indicate nonpoint source pollution influences on the tributary streams. Appropriate flow data were not available to support these indications by regression analyses. Data on the Juniata River at Mapleton indicate that point source discharges are the primary contributors of oxidized inorganic nitrogen, while downstream at Newport, the data indicates that nonpoint sources exert the major influence on the river. Regression analyses of oxidized inorganic nitorgen data from Mapleton and Newport support these indications. This reach of the Juniata River experiences major nonpoint source influence and probably reflects the nonpoint source influences on the tributary streams.

Mean concentrations of ammonia generally show some increase during the higher flow periods in the upper reaches of the Juniata River above Mapleton, indicating that the primary inflows of ammonia are from nonpoint sources. Exceptions were noted at sampling stations on the Beaverdam Branch Juniata River near the confluence with the Frankstown Branch and on the Juniata River near Huntingdon. The mean concentrations at these stations show a decreasing trend with increasing flows, indicating that point sources are the primary contributors of ammonia. In the lower reach of the Juniata River from Mapleton downstream to Newport, the mean concentrations of ammonia at Mapleton indicate that nonpoint sources of ammonia have major influence on the river. Data for the upper reaches of the Kishacoquillas Creek above Reedsville, Aughwick Creek and Jacks Creek (tributaries to the Juniata River), show an initial decrease in concentration during the moderate flow period, then an increase during the high flow period; however, the high flow concentration does not exceed the low flow concentration. The increase in concentration between the moderate and high flow periods suggests that if sufficient data were collected the indications may be that nonpoint sources exert a major influence on these streams. Data from sampling stations on the lower reach of the Kishacoquillas Creek and on the Tuscarora Creek indicate that nonpoint sources of ammonia are the major contributors to the stream. Mean concentrations of ammonia in the Juniata River at Newport show an initial decrease then an increase in concentration during the high flow period exceeding that of the low flow period, indicating possible nonpoint source influence.

Regression of ammonia data to determine flow-concentration relationships generally support the indications derived from mean concentrations at the sampling stations where appropriate flow data were available. Ammonia concentrations increased with increasing flows at all stations except on the Frankstown Branch Juniata River. Although the mean concentrations on the Frankstown Branch indicated an increase in concentration with increased flows, the regression analyses indicated the opposite phenomenon.

Phosphorus data show a decrease in mean concentrations during the higher flow periods for most stations located in the Juniata River drainage area indicating that point sources exert the primary influence on phosphorus concentrations in the streams. Only one station located on the South Bald Eagle Creek at Tyrone showed phosphorus concentrations that indicated nonpoint source influence.

Regression analyses of phosphorus data also generally supported the indications from the mean concentrations that point sources were the primary contributor of phosphorus. Exceptions were noted for the monitoring station on the South Bald Eagle Creek where mean concentrations indicated probable major nonpoint source influence, but the regression analyses indicated primarily point source influence. Also, on the Juniata River at Newport, mean concentrations indicated probable point source influence, but regression analyses indicated nonpoint source influence. Information on point source discharges not available for this study is needed to determine the major sources of phosphorus.

Evaluation of the data for the Juniata River drainage area indicates that the major part of the upper reaches above Mapleton is influenced primarily by point sources of inorganic oxidized nitrogen. The Raystown Branch, Juniata River and the lower reach of the Juniata River below Mapleton experience major nonpoint source contributions of oxidized inorganic nitrogen. Ammonia appears to be contributed primarily from nonpoint sources during the periods of high flows throughout the drainage area. Point source discharges appear to be the primary sources of phosphorus in the drainage area.

The results of the EPA Annapolis Field Office nutrient transport study conducted near the mouth of the Juniata River indicated that nonpoint sources of oxidized inorganic nitrogen were the major contributor to the Juniata River. Point discharges were the primary sources of TKN and phosphorus according to the EPA study.

<ins>Conodoguinet Creek</ins> - The Conodoguinet Creek drainage area lies in the southern part of the Valley and Ridge Province which has lower

slopes and broader valleys. Major land uses in the drainage area consist of about 45 percent agricultural land, 38 percent forest and five percent urban lands. The uppermost reaches of the drainage areas are predominantly in forest lands and the lower reaches are primarily in agriculture. Nutrient data collected at two stations on the Conodoguinet Creek indicate that the major contributors of oxidized inorganic nitrogen, ammonia and phosphorus are point source discharges. Mean concentrations of nutrients at the station in Middlesex Township indicated a dilutional effect during the higher flow periods. Regression of nutrient concentration and flow data corroborated the impressions derived from the mean concentration that point sources are the major contributors of oxidized inorganic nitrogen, ammonia and phosphorus. Although flow data corresponding to the chemical data were not available for corroboration, mean concentration of nutrients at the monitoring station downstream in Hampden Township also indicated that oxidized inorganic nitrogen and phosphorus concentrations were diluted during higher flow periods. Ammonia data indicates that the concentrations increased with flows, implying that nonpoint sources made a major contribution into the Conodoguinet Creek between the Middlesex Township station and the Hampden Township station. The EPA Annapolis Field Office sampled near the mouth of the Conodoguinet Creek downstream from the Hampden Township monitoring station during their nutrient transport study. The results of the study indicated that nonpoint sources had a major influence on oxidized inorganic nitrogen in the Conodoguinet Creek. The EPA phosphorus and TKN data indicated that point sources were the major sources of these parameters.

Yellow Breeches Creek - The Yellow Breeches Creek lies primarily along the southern boundary of the Valley and Ridge Province which has lower slopes and broader valleys. It also lies in the northern edge of the Blue Ridge Province which is characterized by moderately steep mountains and heavy forests. Major land uses in the drainage area consist of approximately 39 percent agricultural land, 53 percent forest and one percent urban lands. The southern part of the drainage area is predominantly forested and the Yellow Breeches Creek generally flows along the fairly distinct border between the northern agricultural lands and the forested land. Nutrient data indicated that the mean concentrations of oxidized inorganic nitrogen and phosphorus decreased during the higher flow periods. Mean concentrations of ammonia decreased during the moderate flow period and then increased during the high flow period. Regression analyses to determine flow-concentration relationships resulted in negative relationships indicating a dilutional effect on nutrients from point sources during higher flows. The results of the EPA nutrient transport study conducted at the same location showed positive relationships between flows and concentrations for oxidized inorganic nitrogen, TKN and total phosphorus, indicating major nonpoint source contributions. Additional data are required to clarif the differences in results and to identify the sources of nutrients.

Swatara Creek - The drainage area lies within the eastern part of the Valley and Ridge Province consisting of low hills and moderate relief. Major land uses in the drainage area consist of 52 percent agricultural land, 37 percent forest, seven percent disturbed land and one percent urban land. The ridge along the northern boundary of the Swatara Creek drainage area is predominantly forested and the upper reaches of the watershed are disturbed by mining activities. The remaining area is primarily in agriculture. Mean concentrations of oxidized inorganic nitrogen and phosphorus show a decrease in concentration during the higher flow periods, indicating a dilutional effect on primarily point source discharges. Ammonia concentrations show an increase in concentrations, indicating primarily nonpoint source contributions of ammonia. Corresponding flow data were not available to statistically determine the flow-concentration relationship to support the indications derived from the mean concentrations. The results of regression analyses conducted in the EPA nutrient study at the same location on the Swatara Creek showed small positive slopes for oxidized inorganic and TKN, implying nonpoint contributions; and a negative relationship between flow and concentration of phosphorus, indicating dilution of point source discharges.

W. Conewago Creek - The Conewago Creek watershed is located in the Piedmont Province and consists of low hills in the northern part of the watershed and gently rolling terrain in the major part of the watershed. Major land use in the drainage area consists of about 54 percent agricultural land, 34 percent forested land and two percent urban land. The agricultural and forest lands are fairly well interspersed, with the exception that the Conewago Lake drainage area is predominantly forested. Mean concentrations of oxidized inorganic nitrogen, ammonia and phosphorus showed a decrease in concentrations during the moderate flow period and then an increase during the high flow period. Regression analyses of the nutrient and flow data resulted in positive slopes for all three of the above mentioned parameters, indicating that nonpoint sources exert a major influence on the W. Conewago Creek.

Results of the EPA nutrient transport study at the same location near the mouth of the Creek indicated major nonpoint sources of oxidized inorganic nitrogen and TKN. The study indicated that point discharges were the primary sources of phosphorus.

Codorus Creek - The Codorus Creek drainage area lies in the Piedmont Province and consists of gently rolling to hilly terrain. Major land uses in the drainage area consist of 53 percent agricultural land, 27 percent forest, five percent urban land and two percent disturbed lands. The forested lands in the drainage area are dispersed within the agricultural land; there are no distinctively large forested land areas as compared with the other subbasins. Mean concentrations of oxidized inorganic nitrogen, ammonia and phosphorus data collected on the South Branch Codorus Creek near York showed a decrease during the moderate flow period and then increased during the high flow period. Regression analysis to determine the flow-concentration relationships resulted in positive slopes for all parameters, indicating major nonpoint source contributions of oxidized inorganic nitrogen, ammonia and phosphorus into the South Branch Codorus Creek.

The EPA Annapolis Field Office sampled the Codorus Creek near its mouth during the conduct of the nutrient transport study. The results of that study showed a positive relationship between oxidized inorganic nitrogen concentration and flow, indicating nonpoint source pollution. The EPA results for phosphorus and TKN showed a negative relationship between concentrations and flows which indicate dilution of phosphorus and TKN from primarily point sources.

Conestoga River - The Conestoga River drainage area lies in the Piedmont Province and consists of gently rolling terrain. Major land uses in the drainage area consist of 59 percent agricultural lands, 31 percent forested lands, one percent urban areas and one percent disturbed lands. The forested lands are located primarily along the northern boundary of the drainage area with the agricultural lands being the dominant land use feature for the major part of the drainage area. Two monitoring stations are located on the Conestoga River. Mean concentrations of oxidized inorganic nitrogen, ammonia and phosphorus at Lancaster showed an increase during the higher flow period. Regression analyses of nutrient data also show a positive relationship between flow and concentration, indicating that major nonpoint sources of inorganic nitrogen, ammonia and phosphorus affect the Conestoga River upstream of this station. Nutrient data collected from the Conestoga River at Rock Hill, Pennsylvania, downstream of Lancaster, show that mean concentrations of oxidized inorganic nitrogen and ammonia increased during the higher flow periods.

Mean concentrations of phosphorus decreased slightly during the moderate flow period and then increased during the high flow period. Appropriate flow data were not available to corroborate these indications by regression analyses. The results of the EPA nutrient study near the mouth of the Conestoga River indicated that nonpoint sources were the major contributor of oxidized inorganic nitrogen, and that the primary sources of TKN and phosphorus were point source discharges.

Pequea Creek - The Pequea Creek drainage area lies in the Piedmont Province and consists of gently rolling terrain. Major land uses in the drainage area consist of about 60 percent agricultural land, 26 percent forest land, one percent urban and two percent disturbed land. Mean concentrations of oxidized inorganic nitrogen, ammonia and phosphorus show an increase in concentration during the higher flow period, suggesting a positive relationship between flows and concentrations, but appropriate flow data were not available to support these indications through regression analyses. Results of the EPA nutrient study conducted at a station about two miles upstream indicated that nonpoint sources were the major sources of oxidized inorganic nitrogen, TKN and phosphorus in Pequea Creek during high flows.

Deer Creek - The Deer Creek drainage area lies in the Piedmont Province and consists of gently rolling terrain. The major land uses in this drainage area consist of approximately 65 percent agricultural land, 29 percent forested land, less than one percent urban and other lands. The forest lands are fairly evenly distributed throughout the drainage area. In the upper reaches of Deer Creek the forested lands appear to border the stream banks to a greater extent, while larger segments of the lower reaches of Deer Creek are bordered by agricultural lands. Nineteen sampling stations, from which limited nutrient data were available, are located on Deer Creek and its tributaries.

Nutrient data were collected from five monitoring stations in the upper reaches of Deer Creek above Green Road crossing (about 6.8 miles below the Pennsylvania-Maryland border). Mean oxidized inorganic nitrogen concentrations from these stations generally show a decrease in concentration during the higher flow period, indicating dilution of primarily point source discharges. Regression analyses for flow-concentration relationships of the data from these five stations and also from the Green Road crossing station resulted in a negative relationship which supports the indications of minimal nonpoint source contributions. Mean concentrations for the remaining thirteen stations below the Green Road crossing on Deer Creek indicated an increase in oxidized inorganic nitrogen concentrations, which suggest major nonpoint sources of this nutrient in the lower reaches. Appropriate flow data were not available for these thirteen stations to corroborate the indicated flow-concentration relationships.

Mean concentrations of ammonia in the upper reaches increased slightly during the high flow period, indicating some influence from nonpoint sources. Regression analysis of the data resulted in a negative relationship, which indicates that the primary sources of ammonia are point source discharges.

Mean concentrations of ammonia for the stations in the reach below the Green Road crossing on Deer Creek generally show a decrease in concentration during the high flow period, indicating primary point source influence in the lower reaches of Deer Creek. Flow data were not available to corroborate these indications.

Phosphorus data show that concentrations increase during the moderate flow period then decrease during the high flow period in Deer Creek at Harris Mill Road crossing, Ebaughs Creek at Harris Mill Road crossing, and Deer Creek at Bond Road crossing. Data from the unnamed tributary at Lieb Road crossing show an increase in concentration during the high flow period. Regression analyses of the data resulted in positive flow-concentration relationships for Deer Creek at Harris Mill Road crossing and Ebaughs Creek at Harris Mill Road crossing, indicating that nonpoint sources of phosphorus had a major influence on these streams near these locations. Regression analyses of data from Deer Creek at Bond Road crossing and the unnamed tributary at Lieb Road crossing indicated point source influences of phosphorus. Point source influences of phosphorus were indicated on Little Deer Creek about 0.7 mile above its confluence with Harris Mill Creek, and nonpoint source influences were indicated on Deer Creek at Green Road crossing. Mean concentration data for the lower reaches of Deer Creek below the Green Road crossing indicate a dilution of phosphorus concentrations from point source discharges. Flow data were not available for corroboration by regression analyses.

COMPARISON OF SUBBASINS

Results of regression analyses to determine flow and nutrient concentration relationships for those drainage areas with sufficient data are shown in Table 3. The parameters that showed a positive relationship between flows and concentrations were labelled "NPS" for nonpoint source and those with a negative relationship were labelled "p" for point source.

Table 3

Flow - Concentration Relationships for NO_2-NO_3, NH_3 and TP

Stream Station	Constituent		
	NO_2-NO_3	NH_3	TP
Pennsylvania			
Shamokin Creek nr. Shamokin	NPS	P	NPS
Mahantango Creek nr. Dalmatia	NPS	NPS	NPS
Conodoguinet Creek in Middlesex Twp.	P	P	P
Yellow Breeches Creek nr. Fairview	P	P	P
W. Conewago Creek nr. Manchester	NPS	NPS	NPS
S. Br. Codorus Creek at York	NPS	NPS	NPS
Conestoga River at Lancaster	NPS	NPS	NPS
Juniata River at Newport	NPS	NPS	NPS
Frankstown Br., Juniata River, in Woodbury Twp.	P	P	P
Little Juniata River at Spurce Creek	P	NPS	P
S. Bald Eagle Creek at Tyrone	P	NPS	P
Juniata River at Huntingdon	P	NPS	P
Dunning Creek at Belden	NPS	NPS	P
Raystown Br. nr. Saxton	NPS	NPS	P
Juniata River at Mapleton	P	NPS	P
Maryland			
Little Deer Creek off Harris Mill Road 0.7 Mile above Mouth	P	P	P
Deer Creek at Harris Mill Road Crossing	P	P	NPS
Ebaughs Creek at Harris Mill Road Crossing	P	P	NPS
Deer Creek at Bond Road Crossing	P	P	P
Unnamed Tributary at Lieb Road Crossing	P	P	P
Deer Creek at Green Road Crossing	P	P	NPS

The slopes of the regression equations for the stations indicating major nonpoint source contributions of oxidized inorganic nitrogen, ammonia and phosphorus were similar and small. No clear conclusions could be drawn from the regression analyses as to which of the streams experience the greatest nonpoint source contributions. Probable exceptions were noted for ammonia in the Conestoga River at Lancaster and the Juniata River at Mapleton, where the slopes of the regression equations were large and correlations between flow and concentration were high.

Impressions derived from the average concentrations for the stations at which flow data were not available are shown in Table 4. The parameters for which the mean concentrations suggested an increasing tendency during higher flow were marked with a plus sign (+), and a minus sign (-) was used for those parameters that suggested a decreasing concentration with higher flow.

Flow data for the streams listed above were not available to support the interpretation of the mean concentration data, but the information provides a gross comparison of the streams to determine which streams may be affected by major nonpoint sources of nutrients This assumption is based on the fact that interpretation of mean concentration data and regression analyses were in agreement for the majority of the monitoring stations at which appropriate flow and concentration data were available.

Table 5 shows the average loadings of oxidized inorganic

Table 4

Mean Concentration and Mean Flow Relationships

Stream Station	Parameter		
	$NO_2 + NO_3$	NH_3	TP
Penns Creek near Mouth	+	+	-
Mahanoy Creek near Mouth	+	+	-
Wiconisco Creek at Millersburg	+	+	-
Conodoguinet Creek in Hampden Twp.	-	+	-
Swatara Creek at Middletown	-	+	-
Conestoga Creek at Rock Hill	+	+	+
Pequea Creek in Martic Twp.	+	+	+
Juniata River Tributaries			
Beaver Dam Br. near Confl. with Frankstown Branch	-	-	-
Little Juniata in Antis Twp.	-	+	-
Bobbs Creek at Reynoldsdale	+	+	-
Aughwick Creek at Aughwick Mills	+	-	-
Kishacoquillas Creek at Reedsville	+	-	-
Honey Creek at Reedsville	+	-	-
Kishacoquillas Creek in Derry Twp.	+	+	-
Kishacoquillas Creek at Lewistown	-	+	-
Jacks Creek at Lewistown	+	-	-
Tuscarora Creek at Port Royal	-	+	-
Deer Creek at Carea Road Bridge	+	-	-
Big Br., Deer Creek at Eden Mill Rd.	+	-	-
Falling Br., Deer Creek at Red Bridge Road	+	-	-
Deer Creek at Bridge on Md. 165	+	-	-
Little Deer Creek, Deer Creek at Bridge on Md. 165	+	-	-
Deer Creek at St. Clair Bridge Rd.	+	-	-
Deer Creek at Cherry Hill Rd. Bridge	+	-	-
Deer Creek at Walters Mill Road Above Stout Bottle Br.	+	-	-
Deer Creek at U. S. Rt. 1	+	-	-
Deer Creek at Md. 136 Bridge	+	-	-
Deer Creek at Noble Mill Road Bridge	+	-	-
Deer Creek at Stafford Bridge Rd.	+	-	-
Deer Creek, Mouth at Railroad Bridge	+	-	-

TABLE 5

AVERAGE OXIDIZED INORGANIC NITROGEN, AMMONIA AND TOTAL PHOSPHORUS LOADINGS FOR MONITORING STATIONS IN THE LOWER SUSQUEHANNA RIVER BASIN, IN POUNDS PER DAY

Station	Flow (cfs)			$NO_2 + NO_3$			NH_3			TP as P		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Shamokin Crk. in Shamokin Twp.	54	98	93	73	327	465	757	664	510	347	103	278
Mahantango Crk. nr. Dalmatia	60	251	261	771	3,808	4,732	25	485	143	25	94	98
Juniata River												
Frankstown Br. Juniata R.	128	459	948	1,544	7,001	9,540	70	285	1,150	266	668	894
Little Juniata R. at Spruce Crk.	181	224	600	1,540	1,738	3,602	100	221	346	386	534	689
S. Bald Eagle Crk.	86	66	117	232	172	303	27	22	107	68	27	217
Juniata R. at Huntingdon	378	869	1,931	4,156	9,194	14,280	350	248	1,384	692	890	1,207
Dunning Crk. nr. Mouth	45	112	612	430	638	4,489	21	42	494	45	36	264
Raystown Br. at Rt. 913 Bridge nr. Saxton	458	409	747	2,770	3,699	4,695	284	110	552	383	154	334
Juniata R. at Mapleton	765	1,933	3,258	5,670	11,252	21,318	519	5,241	2,687	990	1,771	1,809
Juniata R. at Newport	1,306	3,196	7,722	4,885	11,266	48,947	545	1,206	5,827	999	1,033	5,078
Conodoguinet Crk. at T574 Bridge in Middlesex Twp.	354	393	977	6,279		13,007	267		484	562		1,722

Station	Flow (cfs)			$NO_2 + NO_3$			NH_3			TP as P		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Yellow Breeches Crk. at Old U. S. 111 Bridge Fairview Twp.	189	208	441	2,388	1,904	4,119	99	56	238	161		285
W. Conewago Crk. nr. Manchester	140	357	2,965	1,010	1,574	33,033	103	57	3,308	137	212	3,196
S. Br. Codorus Crk. at York	42	47	140	833	767	3,144	41	8	149	22	18	88
Conestoga Crk. at Lancaster	264	366	440	9,152	17,851	19,753	88	280	538	381	497	1,210
Ebaughs Crk. at Harris Mill Road Crossing	8.42	23.40	15.15	172.46	592.79	290.70	1.36	1.26	3.27	1.36	6.31	1.63
Little Deer Crk. off Harris Mill Road 0.7 Mile Above Mouth	0.72	2.90	2.31	13.35	50.17	34.11	0.08	0.16	0.50	0.62	1.72	0.25
Deer Cr. at Harris Mill Road Crossing	12.20	34.80	38.80	254.48	656.50	625.30	1.97	1.87	8.36	3.29	16.88	6.27
Deer Crk. at Bond Road Crossing	2.85	68.10	68.70	57.30	928.66	1033.11	0.31	3.67	14.81	0.15	40.38	3.70
Unnamed Trib. at Lieb Road Crossing	1.18	2.62	2.64	24.49	24.01	39.84	0.19	0.14	0.57	0.19	0.28	2.42
Deer Crk. at Green Road Crossing	29.27	91.70	83.27	569.53	1037.95	1328.52	3.15	4.94	17.95	23.66	54.37	8.98

nitrogen, ammonia and phosphorus for each subbasin. The Juniata River shows the greatest loads of oxidized inorganic nitrogen, ammonia and phosphorus during the March-May high flow season as compared to the other subbasins. The W. Conewago Creek and Conestoga River also show high oxidized inorganic nitrogen loadings during the high flow season. The W. Conewago Creek shows high ammonia and phosphorus loadings during the high flow season.

Table 6 shows the loadings for those stations with appropriate flow and chemical data in pounds-per-day-per-square mile. The greatest loadings of oxidized inorganic nitrogen for all seasons were found in the Conestoga River. The Shamokin Creek had the greatest ammonia loadings per square mile for all seasons. These loadings were primarily from point sources as indicated by regression analysis. Shamokin Creek also recorded the greatest phosphorus loadings during the high flow season.

The loadings shown in Tables 5 and 6 reflect both point and nonpoint source loadings. Appropriate point source discharge information was minimal and incomplete; therefore, separation of point source loads from stream loads was not possible. The data cannot be used to compare the nonpoint source contributions for each stream, but the loadings provide a relative comparison of total nutrient loads in each drainage area. No clear conclusions could be made; however, based on data in Table 6, it appears that the Conewago Creek and the Conestoga River may have the greatest nonpoint source loads of oxidized inorganic nitrogen. The Conewago Creek appears to have the greatest nonpoint source loads of ammonia

TABLE 6

AVERAGE LOADING
IN POUNDS PER DAY PER SQ. MI.

Station	$NO_2 + NO_3$			NH_3			TP as P		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Shamokin Creek	1.35	6.03	8.58	13.97	12.25	9.41	6.40	1.90	5.13
Mahantango Creek	4.76	23.51	29.21	00.15	2.99	0.88	0.15	0.58	0.61
Juniata River									
Frankstown Br.	5.31	10.48	32.78	0.24	0.98	3.95	0.91	2.29	3.07
Little Juniata R.	7.00	7.90	16.37	0.45	1.00	1.57	1.75	2.42	3.13
S. Bald Eagle Creek	5.26	3.90	6.87	0.61	0.50	2.43	1.54	0.61	4.92
Juniata R. at Huntingdon	5.09	11.27	17.50	0.43	0.30	1.70	0.85	1.09	1.48
Dunning Cr. nr. Mouth	2.50	3.71	26.10	0.12	0.24	2.87	0.26	0.21	1.53
Raystown Br. nr. Saxton	3.66	4.89	6.21	0.38	0.15	0.73	0.51	0.20	0.44
Juniata R. at Mapleton	2.79	5.54	10.50	0.25	2.58	1.32	0.49	0.87	0.89
Juniata R. at Newport	1.46	3.36	14.59	0.16	0.36	1.74	0.30	0.31	1.51
Conodoguinet Creek	14.81		30.68	0.63		1.14	1.33		4.06
Yellow Breeches Creek	11.06	8.82	19.07	0.46	0.26	1.10	0.75		1.32
W. Conewago Creek	1.98	3.09	64.77	0.20	0.11	6.49	0.27	0.42	6.27
S. Br. Codorus Creek	7.12	6.56	26.87	0.35	0.07	1.27	0.19	0.15	0.75
Conestoga Creek	28.25	55.10	60.97	0.27	0.86	1.66	1.18	1.53	3.73
Deer Cr. at Green Rd. Crossing	3.35	6.11	7.82	0.02	0.03	0.11	0.14	0.32	0.05

and phosphorus. Both of these streams flow through predominantly agricultural watersheds.

Comparison of SRBC and EPA Results

The personnel of the Environmental Protection Agency Annapolis Field Office conducted a nutrient transport study during June 1971 - May 1972 of the lower Susquehanna River Basin (Clark, Guide & Pheiffer, 1974). The results of that study, with regard to indications of major nonpoint or point source contributions of oxidized inorganic nitrogen and phosphorus, are tabulated in Table 7 with the results of this study. The notations "NPS" indicate nonpoint source for those stations that resulted in a positive slope of the regression equations and "P" for point source for those stations resulting in a negative slope.

The nutrient data for Penns Creek, Yellow Breeches Creek, Swatara Creek and W. Conewago Creek were collected at the same locations for both the EPA study and for this study. The results of nitrite-nitrate data analyses were the same in both studies for Penns Creek and W. Conewago Creek while it differed for the Yellow Breeches Creek and Swatara Creek. Phosphorus data analyses agreed for Penns Creek and Swatara Creek and disagreed for the Yellow Breeches Creek and W. Conewago Creek. The conflicting results indicate that the data utilized do not reflect long term average conditions in these streams and that additional data is necessary to adequately evaluate the situation.

TABLE 7

COMPARISON OF SRBC AND EPA STUDY RESULTS FOR OXIDIZED INORGANIC NITROGEN & PHOSPHORUS

DER/USGS Stream Monitoring Station	Results $NO_2 + NO_3$ SRBC	 $NO_2 + NO_3$ EPA	 TP SRBC	 TP EPA	EPA Sampling Station
Shamokin Crk. nr. Shamokin	NPS	NPS	NPS	P	Shamokin Crk. nr. Mouth (Downstream)
Penn Crk. nr. Mouth*	NPS	NPS	P	P	Penn Crk. nr. Mouth (Same Location)
Juniata R. at Newport	NPS	NPS	NPS	P	Juniata R. nr. Mouth (Downstream)
Conodoguinet Crk. in Middlesex Twp.	P		P		
Conodoguinet Crk. in Hampden Twp.*	P	NPS	P	P	Conodoguinet Crk. nr. Mouth (Downstream)
Yellow Breeches Crk. in Fairview Twp.	P	NPS	P	NPS	Yellow Breeches Crk. in Fairview Twp. (Same Location)
Swatara Crk. at Middletown*	P	NPS	P	P	Swatara Crk. at Middletown (Same Location)
W. Conewago Crk. nr. Manchester	NPS	NPS	NPS	P	W. Conewago Crk. nr. Manchester (Same Location)
S. Br. Codorus Crk. at York	NPS	NPS	NPS	P	Codorus Crk. nr. Mouth (Downstream)
Conestoga Crk. at Lancaster	NPS		NPS		
Conestoga Crk. at Rock Hill*	NPS	NPS	NPS	P	Conestoga Crk. nr. Mouth (Downstream)
Pequea Crk. in Martic Twp.*	NPS	NPS	NPS	NPS	Pequea Crk. in Martic Twp. (Upstream)

* No regression analyses for SRBC results. Based on Mean Concentrations only.

( ) Indicates location relative to SRBC data stations.

Data collection sites in the EPA study for the other streams listed in Table 7 were generally located downstream of DER/USGS sampling stations.

The results of oxidized inorganic nitrogen data analyses are in agreement that nonpoint sources are the major contributors for these streams. An exception was the Conodoguinet Creek where the results of this study show point sources are the primary contributor of oxidized inorganic nitrogen in the upstream reaches and the EPA study shows that nonpoint sources are the major contributor near the mouth. The results of phosphorus data analyses differed for most of the streams, indicating that nonpoint and point source influences vary in different segments of the same stream.

The EPA nutrient study indicated that the Conestoga River, Swatara Creek and the Juniata River were the major nitrogen contributors in terms of daily loads to the Susquehanna River, and that the major phosphorus contributors were the Conestoga River, Codorus Creek and the Juniata River. The results of this study also indicated that the Conestoga River and Juniata River were the major contributors of nitrogen and phosphorus. However, the results of this study indicated that the W. Conewago Creek was one of the three major contributors of nitrogen and phosphorus. The comparisons made here are questionable in that the sampling locations were different and the data available for this study were not complete for all stations. However, the results of both studies indicate the importance of nonpoint source contributions of nitrogen and phosphorus to the lower Susquehanna River Basin. The EPA Annapolis Field Office (Clark, Donnelly, & Villa, Jr., 1973) further concluded in their study of nutrient enrichment in the upper Chesapeake that the Susquehanna River Basin (the largest tributary to the Bay) was one of two areas most responsible for nutrient contributions in the upper Chesapeake Bay.

Comparison of SRBC Study Results and USGS Sediment Study Results

Generalized results of the U.S. Geological Survey's "Appraisal of Stream Sedimentation in the Susquehanna River Basin" (Williams and Reed, 1972) are listed in Table 8 with the results of this study relative to nonpoint/point source effects for the streams with sufficient data to demonstrate flow-concentration relationship.

Regression analyses of the nutrient data generally indicated nonpoint source influences of phosphorus in the streams draining high sediment yield areas. Phosphorus reacts vigorously with soil and therefore probably is transported with the sediment into the stream. The streams draining moderate and low sediment yield areas primarily reflected point source influence. One exception was noted in the data for the Juniata River at Newport. The results of the EPA Nutrient Transport Study also showed a definite relationship between sediment and phosphorus yields.

Regression analyses of oxidized inorganic nitrogen data indicated major nonpoint source influence on streams draining high sediment yield areas. but indicated both point and nonpoint source influences in low sediment yield areas. Ammonia data also did not reflect any particular relationship.

TABLE 8

COMPARISON OF SRBC RESULTS AND USGS SEDIMENT STUDY RESULTS

	Nutrient			
Station	$NO_2 + NO_3$	NH_3	TP	USGS Sediment Study Results
Shamokin Crk. nr. Shamokin	NPS*	P	NPS	High
Mahantango Crk. nr. Dalmatia	NPS	NPS	NPS	High
Juniata River				Low
Frankstown Br. in Woodbury Twp.	P	P	P	Low
Little Juniata R. at Spruce Crk.	P	NPS	P	Low
S. Bald Eagle Crk. at Tyrone	P	NPS	P	Low
Juniata R. at Huntingdon	P	NPS	P	Low
Dunning Crk. at Belden	NPS	NPS	P	Low
Raystown Br. nr. Saxton	NPS	NPS	P	Low
Juniata R. at Mapleton	P	NPS	P	Low
Juniata R. at Newport	NPS	NPS	NPS	Low
Conodoguinet Crk. in Middlesex Twp.	P	P	P	Moderate
Yellow Breeches Crk. in Fairview Twp.	P	P	P	Moderate
W. Conewago Crk. nr. Manchester	NPS	NPS	NPS	High
S. Br. Codorus Crk. at York	NPS	NPS	NPS	High
Conestoga Crk. at Lancaster	NPS	NPS	NPS	High

*NPS = Nonpoint Source.
P = Point Source.

CONCLUSIONS

Regression analyses for flow-concentration relationships indicate that the Conodoguinet Creek, Yellow Breeches Creek and Deer Creek are affected primarily by point sources of oxidized inorganic nitrogen. Nonpoint sources of oxidized inorganic nitrogen have a major affect on the Shamokin Creek, Mahantango Creek, W. Conewago Creek, South Branch Codorus Creek and the Conestoga River. Major sections of the upper reaches of the Juniata River above Mapleton are affected by point sources of oxidized inorganic nitrogen. The reach below Mapleton is affected by nonpoint sources. Mean concentrations of oxidized inorganic nitrogen indicate that nonpoint sources have a major affect on the other streams considered in this study.

Regression analyses of ammonia data indicate that Shamokin Creek, Conodoguinet Creek, Yellow Breeches Creek and Deer Creek are affected primarily by point sources. Nonpoint sources are the major contributors of ammonia in the Mahantango Creek, W. Conewago Creek, South Branch Codorus Creek, Conestoga Creek and the Juniata River.

Phosphorus data analyses indicate that the Conodoguinet Creek and the Yellow Breeches Creek are affected primarily by point source discharges. Nonpoint sources of phosphorus are major contributors into the Shamokin Creek, Mahantango Creek, W. Conewago Creek, South Branch Codorus Creek, Conestoga River and Deer Creek. The upper reaches of the Juniata River above Mapleton are affected primarily by point source discharges while nonpoint sources are the major contributors of phosphorus below Mapleton.

Nutrient loadings in pounds-per-day-per-square mile indicate that the Conewago Creek and Conestoga River are the greatest contributors of oxidized inorganic nitrogen loadings which are probably from nonpoint sources. The Conewago Creek has the greatest loadings of ammonia and phosphorus.

The highest concentrations of nutrients were recorded in the Conestoga River.

The results of this study indicate that nonpoint sources of nutrients have major influence on certain segments of the streams evaluated, but the extent to which it affects the entire stream is not clear.

Comparison with the results of the USGS appraisal of stream sedimentation indicates that nonpoint sources of phosphorus consistently have a major influence on streams draining areas with high sediment yields, but that nonpoint sources exert a minor influence on streams in moderate and low sediment yielding areas. Nonpoint sources of oxidized inorganic nitrogen were the major sources in high sediment yielding areas, but no definite pattern was shown in the moderate and low sediment yielding areas. No pattern was shown for ammonia.

Additional data collection is necessary to verify the findings in this study. The data used in this appraisal of nonpoint source pollution were collected by other agencies for general stream quality information purposes, therefore it imposed many restrictions. The data available were results of analyses of grab samples which may not necessarily represent the chemistry of the stream throughout the cross section at the sampling site. Initial inventory of stream gaging stations and water quality monitoring stations suggested that data would be plentiful; however, this was not the case in many instances. The type of data collected varied at each station and the locations of sampling stations also restructed the evaluation. This study resulted in only a gross assessment of possible pollution from nonpoint sources.

Point source load data used in this study was incomplete. An inventory of municipal and industrial discharges listed the locations but in many instances flow and effluent quality were not shown.

Interagency coordination for water quality data collection appears to be inadequate. Data available for this study demonstrated the variations in the amount and type of data collected.

Water quality data were retrieved for 119 water quality monitoring stations in the lower Susquehanna River basin below Sunbury, Pa. Of these 119 stations, only 52 stations provided nutrient data. The number of nutrient samples at these stations varied from 4 to 22. Only 22 out of the 52 stations with nutrient data provided corresponding flow data collected at the time of sampling. The remaining 67 stations provided little or no nutrient data or mostly flow data. Collection of nutrient data was not started until 1971 primarily because interest in these parameters was intensified at about this time.

There is a need for developing guidelines which provide a range of nutrient concentrations or nitrogen-phosphorus ratios in healthy streams within the Susquehanna River Basin. These guidelines will then provide a basis for comparison and estimation of the severity of nutrient pollution among the streams of the Basin.

RECOMMENDATIONS

1. Additional data collection should be initiated in the lower Susquehanna River Basin to verify the findings of this study; to delineate definitively tributary stream reaches that demonstrate the effects of nonpoint sources of pollution; to evaluate the impact of nonpoint source pollution on the health of the stream; and to identify the sources and their degree of influence in order to develop control programs.

2. Water quality data collection agencies should coordinate their efforts to develop a sampling network in order to provide uniformity in the type of data collected, improve frequency of samplings, and eliminate data gaps.

3. Priorities for further action should be based on streams shown to be the greatest contributors of nutrients by both this study and EPA Technical Report 60 in order to significantly reduce nutrients into the Susquehanna River and the upper Chesapeake Bay as soon as practicable. Such actions should include the following: collection of water quality data to definitively delineate nonpoint source problem segments in each drainage area; evaluation of agricultural practices and conservation measures; consideration of urban runoff as it relates to the nonpoint source pollution problem; and formulation of control programs.

4. A study should be initiated to develop guidelines which provide a range of nutrient concentrations or nitrogen-phosphorus ratios in healthy streams within the Susquehanna River Basin.

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